NSBRI Neurobehavioral and Psychosocial Factors Team Strategic Plan

8.0 NEUROBEHAVIORAL & PSYCHOSOCIAL FACTORS

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8.1 INTRODUCTION

The success of future International Space Station (ISS) and other low-Earth-orbit missions will depend on prevention, identification and mitigation of neurobehavioral and psychosocial risks to crew health, safety and productivity. Astronauts aboard ISS will continue to endure behavioral challenges for longer periods of time than have been experienced thus far in microgravity. Stressors and risk factors include confinement with a small group of people for up to 8 months; isolation from family and friends; complex communications with Earth including two mission control centers; lack of privacy due to habitability constraints; and cognitive and emotional challenges associated with workload, timeline demands, emergencies, and sustained high level performance. There are also risks to group and individual functioning posed by changes in the structure, organization, and nature of such missions if 30-day shuttle missions are used to augment the science capabilities on ISS. Physical illness, interpersonal strife, equipment failure, and the behavioral challenges posed by maintaining countermeasures for other risks (e.g., daily exercise routines) will at times pose risks to group and individual behavioral effectiveness as missions become longer and the ISS structure ages. Differences in language, culture, gender, and work role will also present challenges to crew communication and effectiveness. Without mitigation, these behavioral stressors individually and collectively have the potential to erode cognitive performance; change neuroendocrine, cardiovascular, and immune responses; disrupt appetite, sleep, and other basic regulatory physiology; lead to neuropsychiatric impairment through anxiety and depression; and potentiate serious interpersonal problems among crewmembers and with Earth-based mission support personnel. The Neurobehavioral and Psychosocial Factors area is concerned with the development of novel ways to monitor individual astronaut neurobehavioral functions, as well as group behaviors, and to provide preventive and operational countermeasures to ensure that astronaut behavioral health is maintained during prolonged missions; that the performance of individual astronauts and the flight team are facilitated; and that crew motivation and quality of life are effectively optimized.

8.2 RISKS

The following risks in the Human Behavior and Performance Discipline of the Critical Path Roadmap have been identified (risk number in parentheses):

- Human Performance Failure Because of Poor Psychosocial Adaptation (18)
- Human Performance Failure Because of Neurobehavioral Dysfunction (21)

The Critical Path Roadmap also lists the following two additional risks under Human Behavior and Performance, but neither of these is encompassed by the NSBRI's Neurobehavioral and Psychosocial Factors Team.

- Human Performance Failure Because of Sleep and Circadian Rhythm Problems (19) is subsumed under the Human Performance Factors, Sleep and Chronobiology area of the NSBRI.
- Human Performance Failure Because Of Human System Interface Problems and Ineffective Habitat, Equipment Design, or Inflight Information and Training Systems (20) is not currently represented in the NSBRI areas, but it is a focus of laboratories at NASA Johnson Space Center and NASA Ames Research Center.

8.3 GOALS

The Neurobehavioral and Psychosocial Factors Team has the following goals for its program:

Risk-Based Goals

Goal 1: *Reduce the risk of human performance failure because of poor psychosocial adaptation.*

Goal 2: *Reduce risk of human performance failure because of neurobehavioral dysfunction*

Non Risk-Based Goals

Goal 3: *Develop objective, unobtrusive methods and approaches to monitor stress, neurobehavioral (cognitive, emotional, social) functions and performance capability during missions*

Goal 4: *Develop ways to effectively use communication modalities and contingencies in order to optimally facilitate team performance and problem solving*

Goal 5: *Develop Earth-based applications of technologies for unobtrusively monitoring stress, neurobehavioral functions and performance to help in early objective detection and intervention for cognitive and emotional impairments associated with stressful life events and compromised behavioral health*

Goal 6: *Develop Earth-based applications of communication modalities and contingencies that prevent errors and misunderstandings, and improve group performance and cohesion in demanding environments and safety-sensitive activities.*

Goal 7: *Integrate research and analysis*

8.4 DESCRIPTION AND EVALUATION OF CURRENT PROGRAM

The Neurobehavioral and Psychosocial Factors Team was formed in 2000, and funded in 2001, following peer-review of applications for research to mitigate risks to both individual behavioral health (i.e., neurobehavioral functions) and group processes (i.e., psychosocial functions) during space flight. Although each of these areas is relatively broad, they do not encompass all of the risks posed to human behavior and performance. As described above, the Critical Path Roadmap lists two additional risks under Human Behavior and Performance, neither of which is addressed by the Neurobehavioral and Psychosocial Factors Team. These include risks to performance posed by circadian disruption and sleep deprivation on orbit, which are being addressed by the Human Performance Factors, Sleep and Chronobiology Team, and risks to individual and group behavioral functioning posed by limitations due to human-system interface and equipment design, which are not currently being addressed by the NSBRI, but which are a focus at laboratories at NASA JSC and ARC.

As currently configured, the Neurobehavioral and Psychosocial Factors Team is primarily focused on reducing the risks of human performance failure due to poor psychosocial adaptation (Goal 1) or neurobehavioral dysfunction (Goal 2). Specifically, the Team seeks to counter the development of psychosocial risks (Goal 1) manifested through inadequate leadership; interpersonal strife or social alienation (e.g., due to gender, culture or status differences); poor group teamwork; lack of crew coordination in problem solving; ineffective communications within the team or with ground controllers; and loss of crew morale. In a parallel manner, other projects on the Team seek to counter risks to neurobehavioral health (Goal 2) manifested through stress reactions; anxiety; depression; loneliness; anger; and neurocognitive impairments. Unlike some areas of NSBRI research, where there is a single source for the biomedical problem (e.g., microgravity effects on muscle or bone), there are a considerable number of factors in prolonged space flight that could create or contribute to neurobehavioral and psychosocial dysfunctions (e.g., excessively scheduled activities and work requirements, poor physiological adaptation to microgravity; interpersonal strife; perceived risks to health; loneliness for family; inadequate communication with Earth; habitability constraints; radiation). Consequently, the countermeasures being developed through the research by the Neurobehavioral and Psychosocial Factors Team necessarily must cover an array of issues and approaches. The following are the various categories of countermeasures likely to be developed as a result of the research on this team:

(1) Selection criteria for optimal crew cohesion, including culture and gender diversity
(2) Training for group living; training for flight and ground crew optimal relations
(3) Guidelines to optimize communication for crew decisions and problem solving
(4) Technologies for monitoring and early diagnosis of cognitive problems, emotional disturbances, and psychosocial dysfunction
(5) Behavioral treatments for stress; affective disorders; and for resolving team conflicts
(6) Pharmacological treatments for stress; affective disorders and serious neuropsychiatric and neurological reactions
(7) Habitability strategies for privacy; and work strategies for motivation and performance
(8) Support for relaxation and leisure activity for enhancing quality of life
(9) Support for assimilating crews psychosocially and neurobehaviorally after return
(10) Novel countermeasure opportunities identified by NASA and through new scientific efforts

(11) Development of a database on the neurobehavioral and psychosocial effects of countermeasures for other biomedical problems in space flight

Ideally, the risks to individual and group behavioral health created by spaceflight are best dealt with through prevention (e.g., a well-integrated crew with optimal pre-flight training and coordination in effective communication, problem-solving, etc.). Therefore one of the focuses of the projects on the Team is to reduce psychosocial risks (Goal 1) by identifying the psychological and behavioral features of individuals and small groups that result in optimal behavioral effectiveness under ground-based (analog) conditions comparable to space flight. This approach is taken in the Antarctic project directed by JoAnna Wood. Other projects directed by Joe Brady, Judith Orasanu, and James Carter seek to determine ways to prevent or resolve psychosocial miscommunication within teams and between space-bound teams and ground controllers.

While prophylaxis against the development of neurobehavioral and psychosocial dysfunctions is ideal, there is no way to guarantee that preventative strategies alone will suffice. The Team therefore also has a strong focus on early detection and resolution of neurobehavioral problems and psychosocial dysfunction. Especially critical is the need for reliable, objective measures of neurocognitive and emotional states and stress reactions. The projects directed by Phillip Lieberman, David Dinges, and Stephen Kosslyn deal directly with obtaining these measures, thus moving towards achievement of non risk-based Goal 3. The emergence of thought and mood disorders during space flight poses very serious risks not only for the individual's behavioral capability but also for the team's performance. Both neurobehavioral and psychosocial problems have occurred in long-duration space flight—with the latter common enough to have resulted in its rating as among the most serious risks (i.e., Type I) in the Critical Path Roadmap; consequently, there remains an acute need to establish reliable, objective, unobtrusive methods for confirmation of stable cognitive and emotional functioning during prolonged human space flight. Without such information available to an astronaut, it will be difficult to ensure that appropriate neurobehavioral countermeasures (e.g., behavioral and pharmacological) will be deployed in a manner that maintains behavioral health. There must be redundant ways to ensure that neurological, neuropsychiatric, or neurocognitive impairments that develop on orbit (regardless of the cause) are quickly identified and treated before they result in a loss of high level performance capacity in a crew member.

The Team also has another major non risk-based goal of finding optimal ways for crews to use communication modalities and techniques to maintain effective group functioning within a flight crew and between the crew and ground controllers, family, and management (Goal 4). Effective communication can help maintain team performance in the face of adversity, and it is one of the best preventative and operational countermeasures for ensuring strong group psychosocial cohesion and performance. Like the development of novel objective, unobtrusive methods and approaches to monitor stress reactions, cognitive state, mood and performance in individual crew members (Goal 3), the establishment of maximally effective communication techniques for all types of contingencies in space flight (Goal 4) will have significant relevance to a host of Earth-based problems (non-risk Goals 5 and 6, respectively).

The problems addressed in the Neurobehavioral and Psychosocial Factors research area generally focus on developing countermeasures for severe stress reactions, depression, cognitive dysfunction, and conflict resolution during long-duration space travel. The initial strategic research agenda for the Team involves eight ground-based studies and two as yet unfunded flight experiments (in feasibility phase at JSC) that collectively address four thematically interrelated questions: What are the effects of culture, personality, and leadership on performance, stress, and health in isolated groups? What are the major influences on interpersonal actions, communications, and problem solving in small groups? How can affective, neurobehavioral and neurocognitive dysfunction be objectively detected in remote locations? What neurobiological processes of stress and arousal are the optimal targets for behavioral and pharmacological interventions? Six inter-related themes define the range of factors critical for improving crew health and safety and for optimizing performance capability: (1) Biological mechanisms of neurobehavioral dysfunction; (2) Motivation, cognition and performance; (3) Individual factors in selection, training, performance; (4) Pharmacology in space; (5) Team and interpersonal optimization; and (6) Organizational, cultural and management factors.

The current Team projects are briefly described below and Table 8.1 summarizes the risks, countermeasure targets, experimental system, and countermeasure development phases for each project. The projects are equally divided between psychosocial risks (projects directed by Wood, Brady, Orasanu, Carter) and neurobehavioral risks (projects directed by Dinges, Lieberman, Kosslyn, Aston-Jones). The final two projects (Brunner, Kanas) are proposed flight experiments in feasibility assessment at JSC, and as such, they are not yet funded. The Brunner project deals with a neurobehavioral countermeasure question, while the Kanas project deals with a psychosocial countermeasure question.

Wood et al.: Individuals and Cultures in Social Isolation

This psychosocial project seeks to increase understanding of the effects of personality, culture, and group characteristics on both individual and group performance in an extreme environment (Antarctica) that parallels many of the conditions likely to occur in long-duration space missions. Identifying those elements of leadership that maximize crew functioning in extreme environments and increasing our understanding of how individual and group factors affect physical and psychological health under prolonged group isolation in Antarctica can be used in identification and design of optimal flight crew configurations as a preventative countermeasure.

Orasanu et al: Distributed Team Decision Making in Exploration Missions

This psychosocial project examines how team structure and communication medium affect the nature and quality of small team interaction, distributed decision making strategies, and problem solving under a variety of stressful conditions (i.e., time pressure, risk level, information accuracy/completeness). It assesses autonomic nervous system markers and the Specific Affect Coding System technology for detecting when crew interactions and decision-making are degrading. Countermeasure targets include identifying ways to optimize crew problem solving performance during demanding and non-demanding periods.

Brady et al.: Psychosocial Performance Factors in Space Dwelling Groups

This psychosocial project seeks to determine effects of variations in the structure and function of communication channels within and between simulated space-dwelling and Earth-based groups. It addresses the effects on psychosocial performance effectiveness of (1) stressful environmental and behavioral interactions; (2) variations in the appetitive and aversive characteristics of incentive control systems; and (3) selection, training and experience. Countermeasure targets include personality characteristics to optimize crew communication and performance and identifying ways to reinforce the appropriate use of communication strategies for optimal problem solving.

Carter et al.: Designing a Smart Medical System for Psychosocial Support

This project seeks to develop a prototypical smart medical system for neurobehavioral and psychosocial support. The computer-based system will address neurobehavioral issues, including the assessment of affect and suggested interventions, and provide a training module on interpersonal conflict resolution. The system will be developed and evaluated with experienced users and content experts. Countermeasure targets include using the system to help detect (via standardized questions) behavioral dysfunction in individual astronauts and among flight crews and having the computer-based system offer suggestions to crews for remediating problems and conflicts.

Dinges et al.: Optical Computer Recognition of Behavioral Stress
This neurobehavioral project seeks to determine whether a state of the art optical computer recognition algorithm based on facial expression can be developed that will objectively discriminate when subjects are undergoing behavioral stressors and negative affect. It also evaluates the effects of different behavioral stressors on physiological responses, on psychological responses, and on performance responses, and explores the magnitude of stress responses relative to the accuracy of an optically based computer recognition algorithm of the face. Countermeasure targets include using the system to objectively detect significant negative affect and emotional dysfunction in astronauts when verbal and self-report communications are not possible or not reliable in order to recommend behavioral and pharmacological countermeasures for affective disorders.

Kosslyn et al.: Quick Assessment of Basic Cognitive Function
This neurobehavioral project seeks to develop a set of brief performance tasks that will be computerized versions of 11 standard tasks from cognitive psychology, which tap the range of basic cognitive abilities. The performance tasks being developed will be very short versions or variants of tasks that will capture the processing differences indicated by scores on the standard tasks and be designed to be self-administered. Countermeasure targets include using the brief tests to objectively detect cognitive performance deficits in individual astronauts, to alert crewmembers to diminished behavioral capacity and the need for rest or other interventions.

Lieberman et al.: Speech Monitoring, Cognitive and Personality Alterations
This neurobehavioral project seeks to develop a system that will detect cognitive deficits, changes in personality and emotional disturbances by means of acoustic measures of speech. The project utilizes data from studies of speech and behavior of individuals in a space analog (Mt. Everest climbers) as well as patients suffering neurodegenerative diseases (Parkinson's) to develop and verify techniques for analysis of conversational speech for detection of cognitive changes. Countermeasure targets include using the system to objectively detect significant personality changes and emotional dysfunction in astronauts when optical recognition and self-report communications are not possible or not reliable in order to recommend behavioral and pharmacological countermeasures for the personality disturbances.

Aston-Jones et al.: Stress, Performance and Locus Coeruleus
This neurobehavioral project seeks to analyze rodent locus coeruleus (LC) activity during a continuous performance task, to determine the effects of acute and repeated stress on changes in LC function and performance, and to identify pharmacological countermeasures to mitigate stress effects on LC activity and attentional function.

Proposed Flight Experiment—Brunner et al.: Effect of Spaceflight on Pharmacokinetics of Psychotherapeutic Agents. This neurobehavioral project seeks to determine the effects of space flight on the pharmacokinetics, pharmacodynamics and the underlying physiologic processes (gastric motility and drug absorption) of the anti-anxiety drug, lorazepam (Ativan®), and the anti-depressant drug, venlafaxine (Effexor®). Countermeasure targets include studying both oral and intravenous use of both drugs to determine ways to maximize their effectiveness for affective disorders and stress reactions that may develop in prolonged space flight, while minimizing their toxicity.

Proposed Flight Experiment—Kanas et al.: Psychosocial Education (PSE) Training for ISS Missions. This psychosocial project seeks to evaluate the effectiveness in five International Space Station (ISS) crews and their support personnel of a 5-hour, pre-launch Psychosocial Education (PSE) training program designed to reduce tension and displacement of dysphoria to outside personnel and to increase cohesion, leader support, expressiveness and personal growth. Countermeasure targets include determining whether the PSE training program can reduce hostility among astronauts and between astronauts and mission ground support personnel while increasing group satisfaction and behavioral effectiveness.

It has been approximately 18 months since the formation and funding of the Neurobehavioral and Psychosocial Factors Team. The 1-2 hour monthly telecons involving all 10 project Principal Investigators, some co-investigators, and Dr. Al Holland (Chief Psychologist from JSC) have already resulted in excellent integration across the broad scope of the projects and a number of planned collaborations. Table 8.2 shows progress at integration efforts for the team to date (Goal 7).

The research goals of the team have excellent relevance to Earth-based applications (Goals 5 and 6). Neurobehavioral and psychosocial dysfunctions characterize a wide range of human conditions, from mood disorders to neurological conditions, to cultural biases and hostilities. Progress in developing techniques and methods for improving objective detection of stress reactions in space flight should be of value in the many contexts on Earth in which there is a need to know how much distress a person is experiencing in order to know when to intervene and with what modality (e.g., evaluation of victims, emergency workers, military personnel, etc.; Goal 5). Similarly, finding ways to enhance effective communication and group problem solving could help in a wide range of contexts in which high level performance and problem solving are essential (e.g., emergency management, power plants, transportation systems, etc.; Goal 6). Finding ways to reduce neurobehavioral and psychosocial risks could also be of value to those treating patients who have cognitive and emotional impairments associated with neuropsychiatric and neurological disorders.

Although the Neurobehavioral and Psychosocial Factors Team does address a range of Critical Path questions that must be answered in order to maintain astronaut behavioral health and group effectiveness in long-duration flights, significant gaps in the program do remain due to current funding limitations. The External Advisory Council (EAC) of the NSBRI rated the current research program of the Neurobehavioral and Psychosocial Team as “very good” in its initial evaluation in September 2000 but expressed concerns regarding the potential limitations of some of the empirical approaches and recommended additional funding be set aside to solicit proposals in those areas identified as gaps in the current team. These views were expressed again in the February 2001 review by the EAC, in which it concluded that although the Team has “great potential,” it was also “very diverse,” and that “there exists a level of complexity that could easily require orders of magnitude additional funding to accomplish their goals.” At that time the EAC went on to state—consistent with the Critical Path Roadmap ranking of risk severity—"the problems addressed by this team are among the most important for long term space travel—attempting to develop countermeasures for severe stress reactions, depression, cognitive dysfunction, and conflict resolution," and that the team could "benefit from support for new methodologies and technologies (e.g., functional magnetic resonance imaging [fMRI], mass resonance spectroscopy [MRS], novel tests of cognitive function, and virtual reality)." Accordingly, if the team gaps are to be closed, in addition to continuing to support the current research projects, the NSBRI needs to support research that addresses the following four questions in the next five years.

1. What behaviors, experiences, intellectual capacities, performance capabilities, personality traits, demographic, interpersonal and leadership styles of crewmembers, as well as gender, age and ethnicity combinations, can be identified during the selection process and be used to select and assemble the best teams for long duration missions?

2. How can novel neuroscience technologies (e.g., neuroimaging via fMRI, MRS, positron emission tomography [PET], near-infrared [NIR] optical imaging; and transcranial magnetic stimulation [TMS]) be used to develop countermeasures for the psychosocial and neurobehavioral effects of prolonged space flight?

3. How can novel behavioral methodologies (e.g., virtual reality; prolonged behavioral monitoring and experimental manipulation of small group microsocieties in isolation and in tandem) be used to develop countermeasures for the psychosocial and neurobehavioral effects of prolonged space flight?

4. What are the effects on neurobehavioral health and psychosocial functioning of the countermeasures devised for other vital physiological systems (e.g., diet, exercise, light exposure for circadian entrainment, and pharmacotherapies used as countermeasures for the effects of radiation, cardiovascular, neurovestibular, bone loss, etc.)?

Tables 8.3a and 8.3b provide projected timelines for achieving Risk Goals 1 and 2, and Non-Risk Goals 3 and 4. They also presume that in the near future, new projects that address the four critical gap questions described in the preceding paragraph will be supported. Table 8.3a deals with countermeasure development to reduce the serious risks posed by poor psychosocial adaptation in space flight, and Table 8.3b deals with countermeasure development to reduce the risks posed by neurobehavioral dysfunction in prolonged space flight.

8.5 OBJECTIVES AND STRATEGIC ACTIVITIES

The objectives underlying each goal are presented below, along with strategic activities that will be used to achieve the goals and objectives.

Goal 1: *Reduce the risk of human performance failure because of poor psychosocial adaptation.*

Objective 1A. Assess risk and target level of acceptable risk

- Determining the full range of psychosocial stressors in space flight continues to be a priority in order to mitigate these stressors. Various team members (Wood, Brady, Kanas, Carter, Buckey, Dinges) have been acquiring information from published reports, JSC personnel, and former and current astronauts on the sources of psychosocial stress.

Objective 1B. Determine mechanisms

- Complete projects that seek to identify predictors of vulnerability to poor psychosocial adaptation environments (Wood, Brady, Orasanu, and Carter projects).
- Complete projects that seek to determine the effects of contingencies on use of communication channels (Brady and Orasanu projects).
- Complete work on establishing astronaut-guided content for a prototypical computerized self-diagnostic system for conflict management (Carter and Buckey project).
- Complete project that seeks to identify interrelationships among social context, cultures, and health in an analog environment (Wood project in Antarctica).
- Complete projects that seek to identify selection criteria for optimizing effective leadership and group cohesion (Wood project).

Objective 1C. Develop countermeasures

- Complete projects that establish effects of training, incentives and experience on communication (Brady and Orasanu projects).Complete project on prototypical computerized self-help system for psychosocial support (e.g., simulated encounters with "virtual crew members") and assessment (adaptation of an existing self-guided psychiatric assessment) (Carter and Buckey project).Complete projects on effects of stressors, gender and cultural differences on problem solving (Orasanu, Wood, and Brady projects).
- Complete projects seeking to develop training to prevent poor psychosocial adaptation (Brady, and Orasanu projects).
- Complete projects seeking to develop a hierarchy of ways to maximize group communication, decision making and problem solving (Orasanu and Brady projects).
- Complete projects that seek to develop insights into factors relevant to training for living well in confinement, away from family (Wood and Kanas projects).
- Complete the development of technologies for early detection of psychosocial dysfunction (Wood, Orasanu, and Brady project).Complete projects that seek to identify optimal interventions for preventing and resolving interpersonal conflicts (Carter and Kanas projects).
- Complete projects that seek to identify techniques to maintain effective flight and ground crew relations (Brady, Orasanu and Kanas projects).
- Continue and expand projects that measure behaviors, experiences, intellectual capacities, performance capabilities, personality traits, demographic, interpersonal and leadership styles of crewmembers, as well as gender, age and ethnicity combinations, that could be used in identification during the selection process to select and assemble the best teams for long duration missions.
- Initiate studies of novel behavioral methodologies (e.g., virtual reality; prolonged behavioral monitoring and experimental manipulation of small group microsocieties in isolation and in tandem) to develop new countermeasures for the psychosocial effects of prolonged space flight.
- Initiate projects that seek to develop strategies for privacy, relaxation, novelty, leisure, and re-acclimation.
- Initiate projects that seek to identify effects on psychosocial functions of novel countermeasures for other risks (e.g., muscle, bone, radiation, neurovestibular, sleep and chronobiology). (This initiative will depend upon the rate at which new and effective countermeasures come on line from other areas. The goal

here is to ensure they do not have adverse effects on communication and other interpersonal functions.)

Goal 2: *Reduce risk of human performance failure because of neurobehavioral dysfunction*

Objective 2A. Assess risk and target level of acceptable risk

- Determining the full range of neurobehavioral stressors in space flight continues to be a priority in order to mitigate these stressors. Various team members (Wood, Brady, Kanas, Carter, Buckey, Dinges) have been acquiring information from published reports, JSC personnel, and former and current astronauts on the sources of neurobehavioral stress.

Objective 2B. Determine mechanisms

- Complete the project that seeks to determine the effects of stress and attentional performance demands on the locus coeruleus to identify novel pharmacological approaches to maintaining performance in the face of high stress (Aston-Jones project).
- Complete projects that seek to identify predictors of vulnerability to cognitive and/or affective dysfunction under stress in analog environments (Wood and Lieberman projects).
- Complete the project on prototypical computerized self-help system for assessment of depression (adaptation of an existing self-guided psychiatric assessment) (Carter and Buckey project).
- Complete the project that seeks to determine if facial expressions reveal physiological stress under performance demands (Dinges project).
- Complete the project that seeks to determine the validity of brief versions of cognitive tests (Kosslyn project).
- Complete the project that seeks to determine if voice-onset time measures cognitive functions (Lieberman project).
- Complete projects that seek to develop technologies that objectively and reliably monitor affective responses (Dinges, Carter, Lieberman and Orasanu projects).
- Complete projects that seek to develop technologies that objectively and reliably monitor neurocognitive responses (Lieberman, Kosslyn, and Dinges projects).
- Initiate and complete the project that seeks to determine pharmacokinetics in space flight (Brunner project).
- Complete projects that seek to identify promising pharmacological countermeasures for stress and mood reactions in space flight (Aston-Jones and Brunner projects).

Objective 2C. Develop countermeasures

- Complete project on prototypical computerized self-help system for assessment of depression and recommended intervention (adaptation of an existing self-guided psychiatric assessment) (Carter and Buckey project).Complete project on development and test of accuracy of optical computer recognition of facial expression of stress (Dinges project).Complete project on establishment of norms and sensitivity of brief cognitive tasks to neurocognitive abilities (Kosslyn project).Complete project on determining whether analysis of common speech can detect cognitive and personality changes in hypoxia climbers on Everest (Lieberman project).
- Initiate project on pharmacological approaches to adverse neurobehavioral reactions (mood, cognition) in space flight.
- Initiate project on behavioral approaches to adverse neurobehavioral reactions (mood, cognition) in space flight.
- Initiate projects to identify adverse CNS / ANS effects from radiation and countermeasures from other areas. (This initiative will depend upon the rate at which new and effective countermeasures come on line from other areas. The goal here is to ensure they do not have adverse effects on cognitive and affective functions. An animal project is underway on the Radiation team (Vasquez project) to evaluate the neurobiological and neurobehavioral effects of simulated space radiation. Ultimately, sensitive neurobehavioral tests will be needed on astronauts if adverse effects are found in rodent models.)
- Initiate projects using novel neuroscience technologies (e.g., neuroimaging via fMRI, MRS, PET, NIR; transcranial magnetic stimulation) to develop countermeasures for the neurobehavioral effects of prolonged space flight.

Goal 3: *Develop objective, unobtrusive methods and approaches to monitor stress, neurobehavioral (cognitive, emotional, social) functions and performance capability during missions.*

Objective 3A. Develop monitoring methods

- Complete projects that seek to determine if objective, unobtrusive measures of facial expressions and speech analysis can detect cognitive, dysfunction and physiological distress during work demands (Dinges and Lieberman projects).
- Complete projects that seek to determine the validity of brief versions of cognitive tests to detect changes in performance capability (Kosslyn project).
- Complete projects that seek to determine whether technologies can be developed for objective detection of psychosocial dysfunction (Wood, Orasanu, and Brady projects).

Objective 3B. Establish best approaches to interpret monitored data

- Initiate projects that study how to best use reliable objective measures of cognitive, affective and psychosocial function/dysfunction to deliver maximally effective countermeasures.

Goal 4: *Develop ways to effectively use communication modalities and contingencies in order to optimally facilitate team performance and problem solving.*

Objective 4A. Enhance effective use of communication systems

- Complete projects that seek to determine the effects of contingencies, stress, modality options and time pressure on effectiveness of communications in problem solving and group performance (Brady and Orasanu projects).

<u>Objective 4B.</u> Establish best approaches to use of communication systems

- Initiate projects that study how to best use communication systems to deal with different levels of performance stressors.

Goal 5: *Develop Earth-based applications of technologies for unobtrusively monitoring stress, neurobehavioral functions and performance to help in early objective detection and intervention for cognitive and emotional impairments associated with stressful life events and compromised behavioral health.*

<u>Objective 5A.</u> Encourage transition of technologies to Earth-based needs.

- Identify applications for monitoring behavioral states in space flight to Earth-based needs. Because neurobehavioral and psychosocial problems are common on Earth (unlike microgravity, which only occurs off planet), the Earth-based applications of technologies for unobtrusively monitoring stress, neurobehavioral functions and performance have considerable potential to help in early objective detection and intervention for cognitive and emotional impairments associated with stressful life events and compromised behavioral health.
- Identification of partners for Earth-based applications of objective technology for cognitive and emotional functions will be undertaken by seeking funding through other interested Federal (e.g., NIH) and private agencies that sponsor research on neuropsychiatric and neurological disorders.

Goal 6: *Develop Earth-based applications of communication modalities and contingencies that prevent errors and misunderstandings and improve group performance and cohesion in demanding environments and safety-sensitive activities.*

<u>Objective 6A.</u> Encourage transition of communication systems to Earth-based needs.

- Finding ways to enhance effective communication and group problem solving could help in a wide range of Earth-based contexts in which high level performance and problem solving are essential (e.g., emergency management, power plants, transportation systems, large scale construction, etc.).
- Identification of partners for Earth-based applications of communication technology and systems for effective team performance will be undertaken by seeking funding through other interested Federal (e.g., DOD) and private agencies that sponsor research on ways to maintaining group functioning in a complex and stressful environment.

Goal 7: *Integrate research and analysis*

<u>Objective 7A</u>. Integrate research within the Neurobehavioral and Psychosocial Factors Team.

- Continue current integration efforts among team PIs, co-investigators and key personnel at JSC as summarized in Table 8.2.

<u>Objective 7B.</u> Integrate research with other teams.

- Continue to build collaborative between the Team projects and projects on other teams, especially other teams with a focus on central nervous system (CNS) functions (e.g., Neurovestibular Team; Radiation Team)
- Coordinate with Human Performance Factors, Sleep and Chronobiology (HPFSC) Team regarding the effects of sleep loss, circadian displacement, and countermeasures for these factors on cognition, mood and social interaction.

- Coordinate with the Neurovestibular Adaptation Team regarding the effects of space motion sickness and countermeasures for it on cognition, mood and social interaction.
- Coordinate with the Nutrition and Rehabilitation Team regarding the potential for nutrition to enhance cognitive, affective and psychosocial functioning as well as the need for neurobehavioral and psychosocial rehabilitation following flight.
- Coordinate with the Smart Medical Systems Team regarding the potential for neuroimaging to enhance objective detection of neurocognitive and neuroaffective dysfunctions in space flight.
- Coordinate with the Immune Team regarding the role of psychosocial and neurobehavioral distress in endocrine and immune responses and the potential of using immune markers as indices of the chronic stress being experienced.
- Coordinate with the Radiation Team regarding the effects of space radiation on neurobehavioral functions in animals as a prelude to assessing effects in humans.

Objective 7C. Integrate research with investigators not formally associated with the NSBRI.

- Although most of the projects on the Neurobehavioral and Psychosocial Factors Team involve collaborations among leading investigators from different schools, universities, companies, and Federal agencies (e.g., projects by Wood, Brady, Orasanu, Dinges, and Carter), Team PIs continue to seek out expertise from scientists not formally part of the NSBRI who are experts in many of the areas under study. In this regard, Dr. Wood has recently begun collaboration with Dr. John Cacioppo, the foremost investigator of social biology, and Dr. Norbert Kraft (National Space Agency of Japan and Commander of a long-duration isolation study) has joined Dr. Orasanu's project.

8.6 SUMMARY

The relatively recent development of the Neurobehavioral and Psychosocial Factors Team reflects the recent categorization of these factors as Type I (severe) risks during prolonged human space flight and the need for novel, evidenced-based approaches to mitigate these risks to ensure the safety and well being of the flight crew and the success of the mission. The Team's current configuration serves well the breadth of the neurobehavioral and psychosocial areas with four ground-based projects in each area, and two as yet unfunded flight projects (one in each area, and both undergoing feasibility review). While the breadth of the research underway is appropriate for the Team's mandate, the current limited number of funded projects restricts experimental depth in any one area. That is, the answers to most of the Critical Path questions for this Team rely on single experiments. Therefore, care in experimental execution and replication of results will be vital to ensure their generalizability to space flight.

Within the next 2-3 years the projects should have sufficient data to determine the viability of some of the basic information and technologies being investigated and begin producing viable countermeasure strategies. Unfortunately this achievement on its own will likely not diminish the controversy that at times surrounds this area—perhaps more so than other areas of space biomedicine, the neurobehavioral and psychosocial area tends to engender pro-con debate about any one countermeasure approach over another when seeking to mitigate the vulnerability of individuals and groups to the psychological, behavioral, and social effects of prolonged space flight. Examples of the contrasting options for countermeasures include: 1) Whether to seek to identify factors relevant to select-in versus select-out criteria; 2) Whether to investigate subjective versus objective techniques for assessing mood, stress, cognitive capability, and psychosocial adaptation; and 3) Whether to study behavioral versus pharmacological countermeasures.

In order to minimize the impact of these traditionally controversial issues, the Team approach has been and will continue to be to obtain the best possible data sets and reliable information and report these findings. We believe that some of the novel perspectives and approaches being attempted in the current team projects will yield new opportunities for countermeasure development. Within 5 years we should be able to have at least one and likely two objective techniques that will be ready for mature countermeasure development (Tables 3a and 3b) in the areas of objective monitoring of neurobehavioral and psychosocial functioning. Similarly, we should be well along in developing priorities for optimal communication techniques under both low and high performance demands. Finally, we should have a clearer idea of the individual characteristics and group dynamic factors that make up optimal behavioral capability under adverse circumstances.

The figure below (Figure 8.1) illustrates the major research themes and anticipated countermeasure types of the current projects and our view that they form critical complementary components to the maintenance of behavioral and psychosocial health and capability during long duration missions. We appreciate the opportunity to work on such challenging scientific questions.

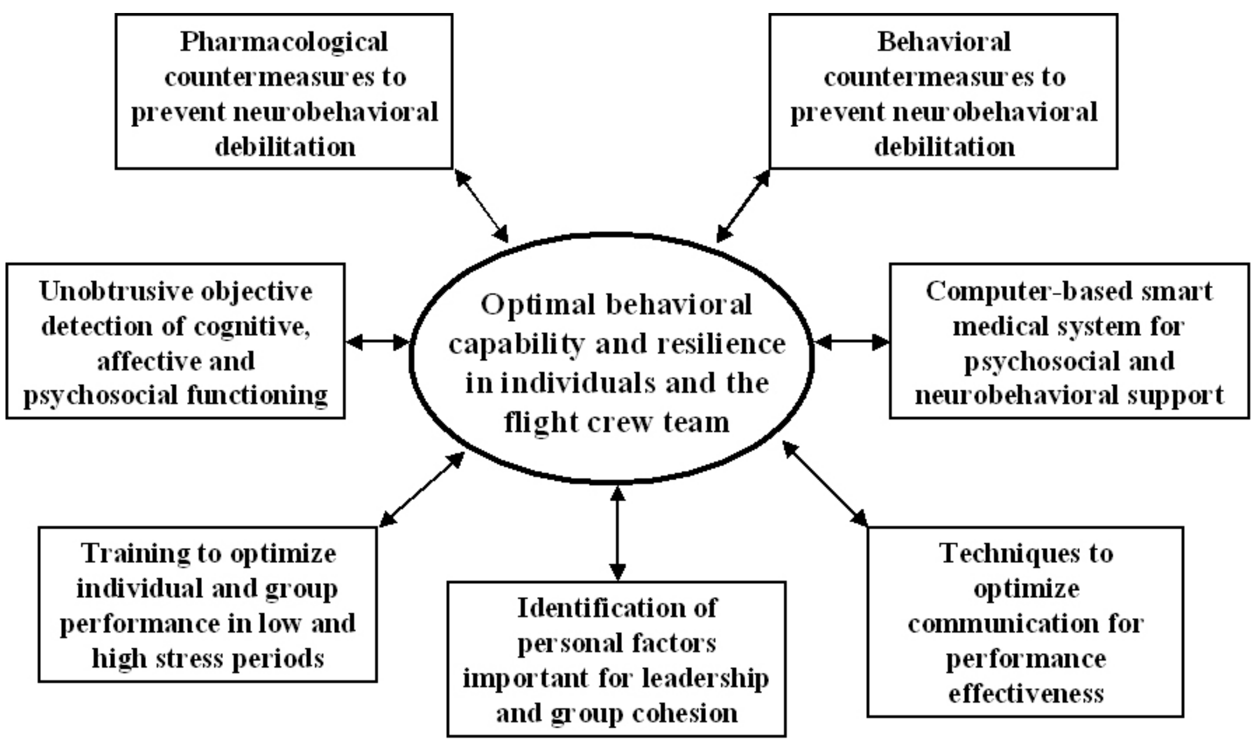

Figure 8.1. Major Research Themes and Currently Anticipated Countermeasure Types.

National Space Biomedical Research Institute
NEUROBEHAVIORAL AND PSYCHOSOCIAL FACTORS PROGRAM

Table 8.1. Project Research Activities

PI/Project	Risk(s) Addressed	Countermeasure Target	Experimental System	Phase 1 Activities: Focused Mechanistic Research	Phase 2 Activities: Preliminary Countermeasure Development Research	Phase 3 Activities: Mature Countermeasure Development Research
ASTON-JONES/ Stress, Performance and Locus Coeruleus	Neurobehavioral dysfunction	Pharmacological agents	Stress and drug effects on LC and performance in rats	Understand stress effects on locus coeruleus		
BRADY/Psychosocial Performance Factors in Space Dwelling Groups	Poor psychosocial adaptation	Training, Environmental manipulation	Humans performing computerized simulation of mission	Determine effects of varying functions of communication channels	Test effects of training, incentives & experience on communication	
CARTER/Designing a Smart Medical System for Psychosocial Support	Psychosocial and neurobehavioral dysfunction	Monitoring & diagnosis procedures; Other (suggestions for treating problem)	Humans developing content from expert & astronaut input	Establish content for prototypical computerized self-diagnostic system	Develop computerized self-help system for psychosocial support	
DINGES/Optical Computer Recognition of Behavioral Stress	Neurobehavioral dysfunction	Monitoring and diagnosis procedures	Humans undergoing high- and low-stress performance	Determine if facial expressions reveal physiological stress	Develop & test optical computer recognition of stress expressions	
KOSSLYN/Quick Assessment of Basic Cognitive Function	Neurobehavioral dysfunction	Monitoring and Diagnosis Procedures	Humans performing on communication simulation	Determine validity of brief versions of cognitive tests	Establish norms & sensitivity of brief to relevant stressors	
LIEBERMAN/Speech Monitoring, Cognitive & Personality Alterations	Neurobehavioral dysfunction	Monitoring and Diagnosis Procedures	Speech evaluations in humans on Everest & Parkinson’s patients	Determine if voice-onset time measures cognitive functions	Test voice analysis to detect cognitive and personality changes	
ORASANU/Distributed Team Decision Making in Exploration Missions	Poor psychosocial adaptation	Training, Other (crew selection)	Humans performing computerized simulation of tasks	Develop technology to monitor affective responses	Establish effects of stressors & gender on problem solving	
WOOD/Individuals and Cultures in Social Isolation	Poor psychosocial adaptation and neurobehavioral dysfunction	Training, Other (crew selection)	Humans wintering over in Antarctica	Identify inter-relationships among social context, cultures, and health		
***BRUNNER**/Effect of Spaceflight on Pharmacokinetics of Psychotherapeutic Agents	Neurobehavioral dysfunction	Pharmacological agents	Humans in space flight	Determine pharmacokinetics of drugs in space flight		
***KANAS**/Psychosocial Education (PSE) Training for ISS Missions	Poor psychosocial adaptation	Training	Humans in space flight		Develop training to prevent poor psychosocial adaptation	Test effectiveness of psychosocial education training in space flight

***Not yet funded; in feasibility phase evaluation at JSC.**

National Space Biomedical Research Institute
NEUROBEHAVIORAL AND PSYCHOSOCIAL PROGRAM

Table 8.2. Integration Activities*

	ASTON-JONES Stress and locus coeruleus	**BRADY** Psychosocial performance	**CARTER** Computerized psychosocial support	**DINGES** Optical computer recognition	**KOSSLYN** Quick assessment of cog. functioins	**LIEBERMAN** Speech monitoring	**ORASANU** Distributed team decision making	**WOOD** Social isolation / Antarctic
Internal Communication	Monthly team telecon; Annual team meeting; NSBRI Retreat; Biannual NASA meeting; National scientific meetings	Monthly team telecon; Annual team meeting; NSBRI Retreat; Biannual NASA meeting; National scientific meetings	Monthly team telecon; Annual team meeting; NSBRI Retreat; Biannual NASA meeting; National scientific meetings	Monthly team telecon; Annual team meeting; NSBRI Retreat; Biannual NASA meeting; National scientific meetings	Monthly team telecon; Annual team meeting; NSBRI Retreat; Biannual NASA meeting; National scientific meetings	Monthly team telecon; Annual team meeting; NSBRI Retreat; Biannual NASA meeting; National scientific meetings	Monthly team telecon; Annual team meeting; NSBRI Retreat; Biannual NASA meeting; National scientific meetings	Monthly team telecon; Annual team meeting; NSBRI Retreat; Biannual NASA meeting; National scientific meetings
Integrated Experiment Development		Complements communication variables in ORASANU project		Assess potential of optical computer recognition for detection of fatigue (with HPFSC Team)			Complements communication variables in BRADY project	
Sample Sharing		Using same psychosocial scales (e.g., alexithymia scale)		Using same psychosocial scales (e.g., alexithymia scale)	Using same psychosocial scales (e.g., alexithymia scale)		Using same psychosocial scales (e.g., alexithymia scale)	
Synergistic Studies of Opportunity				Acquiring speech data in project for LIEBERMAN to analyze		Analyzing speech data from low and high stressor conditions in DINGES		Developing collaboration with Immune project by SHEARER
Development of Computer Model of Integrated Human Function								To be determined--under discussion with BALDWIN

***Although not yet funded, space flight experiments proposed by Brunner (Pharmacokinetics in space flight) and Kanas (PSE training for space flight) are included in monthly Team telecons and annual meetings.**

Table 8.3a. Achieving Goals 1 and 4: Reduce Risk of Human Performance Failure Because of Poor Psychosocial Adaptation

Countermeasure Development Phases	Pre 2001	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Phase 0: Observational & Phenomenological Research													
• Identify psychosocial stressors that occur during prolonged space flight													
Phase 1: Focused Mechanistic Research													
• Identify predictors of vulnerability to poor psychosocial adaptation • Determine effects of contingencies on use of communication channels • Establish content for prototypical computerized self-diagnostic system • Identify interrelationships among social context, cultures, and health													
• Identify selection criteria for optimizing group cohesion													
Phase 2: Preliminary Countermeasure Development Research													
• Establish effects of training, incentives and experience on communication • Develop prototypical computerized self-help system for psychosocial support • Establish effects of stressors, gender and cultural differences on problem solving													
• Develop training to prevent poor psychosocial adaptation • Develop hierarchy of ways to maximize group communication, decision making and problem solving • Develop training for living well in confinement, away from family • Develop technologies for early detection of psychosocial dysfunction • Identify optimal interventions for preventing and resolving interpersonal conflicts • Identify techniques to maintain effective flight and ground crew relations • Develop strategies for privacy, relaxation, novelty, leisure, and re-acclimation • Identify effects on psychosocial functions of novel countermeasures for other risks (e.g., muscle, bone, radiation, neurovestibular, sleep & chronobiology)													
Phase 3: Mature Countermeasure Development Research													
• Develop best select-in criteria for optimizing group cohesion (culture, gender) • Develop best training techniques for crews to optimize group cohesion • Develop optimal communication protocols • Develop full computerized self-help system for psychosocial support													

Table 8.3a (continued). Achieving Goals 1 and 4: Reduce Risk of Human Performance Failure Because of Poor Psychosocial Adaptation

Countermeasure Development Phases	Pre 2001	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Phase 4: Countermeasure Evaluation & Validation													
• Test best select-in criteria for optimizing group cohesion (culture, gender) • Test best training techniques for crews to optimize group cohesion while living in confinement • Test optimal communication protocols • Test techniques to maintain effective flight and ground crew relations • Test full computerized self-help system for psychosocial support and problem solving • Test techniques for early detection of psychosocial dysfunction • Test strategies for optimizing privacy, relaxation, novelty, leisure, and re-acclimation													
Phase 5: Operational Implementation of Countermeasure Strategy													

National Space Biomedical Research Institute

NEUROBEHAVIORAL AND PSYCHOLSOCIAL PROGRAM

Table 8.3b. Achieving Goals 2 and 3: Reduce Risk of Human Performance Failure Because of Neurobehavioral Dysfunction

Countermeasure Development Phases	Pre 2001	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Phase 0: Observational & Phenomenological Research													
• Identify neurobehavioral stressors that occur during prolonged space flight													
Phase 1: Focused Mechanistic Research													
• Understand stress effects on locus coeruleus and attention • Identify predictors of vulnerability to cognitive and/or affective dysfunction under stress in analog environments • Establish content for prototypical computerized self-diagnostic system • Determine if facial expressions reveal physiological stress • Determine validity of brief versions of cognitive tests • Determine if voice-onset time measures cognitive functions • Develop technology to monitor affective responses													
• Understand pharmacokinetics in space flight • Identify promising pharmacological countermeasures for stress and mood reactions in space flight													
Phase 2: Preliminary Countermeasure Development Research													
• Develop prototypical computerized self-help system for neurobehavioral diagnosis and supportDevelop and test optical computer recognition of facial expression of stressEstablish norms and sensitivity of brief cognitive tasksTest voice analysis to detect cognitive and personality changes													
• Establish and test pharmacological approaches to adverse neurobehavioral reactions (mood, cognition) in space flight • Establish and test behavioral approaches to adverse neurobehavioral reactions (mood, cognition) in space flight • Identify adverse CNS / ANS effects from radiation and countermeasures from other areas													

Table 8.3b (continued). Achieving Goals 2 and 3: Reduce Risk of Human Performance Failure Because of Neurobehavioral Dysfunction

Countermeasure Development Phases	Pre 2001	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Phase 3: Mature Countermeasure Development Research													
• Develop full computerized self-help system for neurobehavioral diagnosis and support • Develop best pharmacological approaches to adverse neurobehavioral reactions (mood, cognition) in space flight • Develop best behavioral approaches to adverse neurobehavioral reactions (mood, cognition) in space flight													
• Develop best predictors of vulnerability to cognitive and/or affective dysfunction • Develop best objective (minimally obtrusive, maximally reliable) technique for remote detection of cognitive dysfunction • Develop best objective (minimally obtrusive) technique for remote detection of affective dysfunction													
Phase 4: Countermeasure Evaluation & Validation													
• Test full computerized self-help system for neurobehavioral diagnosis and support • Test best pharmacological approaches to adverse neurobehavioral reactions (mood, cognition) in space flight • Test best behavioral approaches to adverse neurobehavioral reactions (mood, cognition) in space flight • Test best predictors of vulnerability to cognitive and/or affective dysfunction • Test best objective (minimally obtrusive, maximally reliable) technique for remote detection of cognitive dysfunctionTest best objective (minimally obtrusive) technique for remote detection of affective dysfunction													
Phase 5: Operational Implementation of Countermeasure Strategy													